the other. So there is complete failure of the theory of metallic circuits.

But the needed extension is easily made by following Lord Kelvin's method, and using the enlarged meaning of electric current. Let $\mathbf{e}$ be the intrinsic voltage per unit length due to reversible thermal action, and let $\mathbf{C}$ be the current density. Then $\mathbf{eC}$ is the heat per unit volume absorbed per second, and the second thermodynamic law requires that $\Sigma\mathbf{eC}/\theta=0$, if θ is temperature, the summation to be complete as regards $\mathbf{e}$. Here $\mathbf{C}$ may be any circuital current, so $\mathbf{e}/\theta$ is polar; that is, $\mathbf{e}=-\theta\nabla p$, where p is a scalar, the thermoelectric power. In a homogeneous conductor, p is a function of the temperature only, to suit Magnus's results. But it is also a function of the material. In what way is not known, but it shows itself at the junction of different metals. Then p changes, say, from p_1 to p_2, so the intrinsic voltage at the junction is $\mathrm{P}_{12}=\theta(p_1-p_2)$. This is the Peltier force from the first to the second metal. So far is all that is necessary for steady currents. But when the current varies, part of it leaves the metals. Now at a metal-air junction, the thermoelectric power falls from p to 0, so there is an additional thermoelectric force $\mathrm{P}\mathbf{N}$ or $p\theta\mathbf{N}$ acting outwards, $\mathbf{N}$ being the unit normal. It is here assumed that the thermoelectric power of air is zero. It does not seem likely that its value is important compared with p in a metal. This $\mathrm{P}\mathbf{N}$ multiplied by the current leaving the conductor measures the reversible thermal effect at the boundary. The system is now complete, provided there is no external $\mathbf{e}$. But should there be, then it must be counted too, if, for instance, a current is induced in an external conductor. In any case, $\mathbf{e}=-\theta\nabla p$ will be valid, with the usual proper interpretation of discontinuities, and the Maxwellian meaning of the current.

It will be sufficient to suppose that $p=0$ outside a circuit of two metals. Then there is the Thomson force in the metals, the Peltier force at the metal junctions, and the metal-air force $\mathrm{P}\mathbf{N}$ of variable intensity all over the circuit. In the extreme case with which I commenced, there may be only one Peltier force in operation, or even none at all, but just the metal-air force alone. If so, there is reversible evolution of heat at some parts, and absorption at other parts of the boundary.

As regards the application of the second thermodynamic law, it seems to be justified by experimental results with steady currents. I see no reason why it should not be applied to variable currents, even when varying very rapidly. For p is a property of the material and its temperature at any place, and has nothing to do at the moment with what is going on at other places. Yet a reservation is necessary. For the second law results from averages. So there must be some limit to the rapidity with which the current at any spot may vary, if the second law is to be fully valid there.

The Volta contact force must not be forgotten in connection with the metal-air thermoelectric force. Mr. J. Brown has lately made the Volta force disappear by heating it away in oil. If this is fully confirmed, it perhaps proves that chemical action between the metal and an electrolytic film of moisture is the real source of the energy of the transient Volta current, as Mr. Brown maintains. How will this affect the thermal force? If we allow properly for the change in p in passing through the film from the metal to the air, it seems likely that the thermoelectric effects will be simply superposed upon the Volta effects, because the sources of energy are different. Yet they might have to be combined in some unknown way.

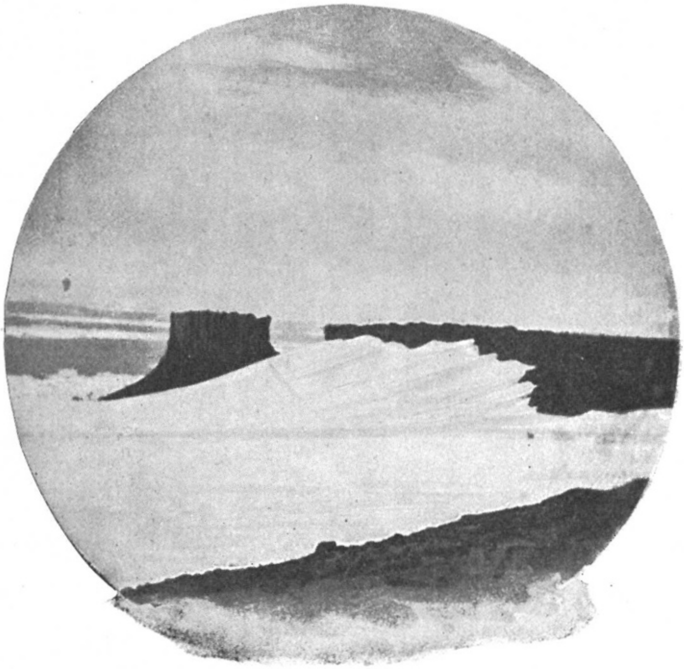
Returning to the steady current in a circuit of two metals, Lord Kelvin showed that the complete intrinsic voltage amounted to $\Sigma p\,d\theta$. This does not express the real distribution of intrinsic force in the circuit, and seems to have no meaning. But it has a curious interpretation, which is of importance in the extended theory. The necessity of the metal-air force is shown in another way. I have shown that the source of $\mathbf{H}$ in varying states is the curl of $\mathbf{e}$ everywhere. Here this is $\mathbf{f}=\mathrm{V}\nabla p\nabla\theta$. It is zero in a homogeneous conductor, and also at the metal junctions, but has the boundary value $\mathrm{V}\mathbf{N}\theta\nabla p$, which would represent the source of $\mathbf{H}$ if there were no metal-air force. But add on the curl of the metal-air force $\mathrm{P}\mathbf{N}$ or $p\theta\mathbf{N}$. It is $-\mathrm{V}\mathbf{N}\nabla\mathrm{P}$, and the sum of the two is $-\mathrm{V}\mathbf{N}p\nabla\theta$. Now this is also the curl of the fictitious intrinsic force referred to, that is, $p\nabla\theta$ in the metals only. So we come to this striking result, that Lord Kelvin's $\Sigma p\,d\theta$ in the metal circuit alone is a fictitious distribution which not only gives the same steady current as the real distribution of intrinsic force, but also gives the true $\mathbf{E}$ and $\mathbf{H}$ everywhere in variable states as well, provided the real intrinsic forces include the metal-air forces along with the Peltier and Thomson forces.

OLIVER HEAVISIDE.

May 18.

THE FARTHEST NORTH.

H.R.H. Prince Luigi Amedeo of Savoy, Duke of the Abruzzi, has given to the English-reading public a superb account of his great Arctic expedition.[1] Though he has fortunately adopted a smaller size of volume than his Imperial namesake, the Archduke Ludwig Salvator, devotes to his luxurious memoirs on Mediterranean islands, the book is still both ponderous and imposing. Although in octavo, it is as large as most quartos, and it is a credit to the publishers in every way. A royal opulence is reflected from the burnished pages, which reflect the light also so perfectly that at night it is impossible, without elaborate precautions, to prevent the image of the lamp-flame from concealing part of the text. The very fine half-tone reproductions of photographs with which the book is crammed profit by the quality of the paper. The portraits of Admiral Markham and Dr. Nansen, illustrating the introduction, are not, however, very happily chosen, and we miss a satisfactory portrait of Captain Cagni, the hero of the memorable journey to the farthest north.



IG. 1.—Cape Säulen, seen from the south-east. (From "On the *Polar Star* in the Arctic Sea.")

The royal author writes modestly and well, his narrative occupying the first volume, and serving to show that he was a good comrade and a brave explorer, sharing all the discomforts of a somewhat miserable wintering without complaint. The translation, too, is well done, running so smoothly that it is rarely recognisable as a translation at all. Now and again, however, little bits of awkwardness come to light. A medical man would hardly write in English of the "digestive tube," nor would a sailor refer to the "left side" or the "chimney" of a steamer—"it's no a lum, it's a funnel," said "Wee Macgreeger" scornfully on one occasion. Trifles of nomenclature also show the want of first-hand knowledge; where the form is so beautiful it jars one to run against a "Thompson" compass, a "Clement" Markham, or even an "Ommaney." We wonder whether the British public nowadays attaches any more definite meaning to a dram as a unit of weight than it does to a gramme; and we are sorry for the task set to poor Dr. Cavalli in weighing out 8oz. 13·0958dr. of tinned meat for each man every day; though we are reassured in finding that the metric units quoted alongside prescribe only the quarter of a kilogramme, and we presume that he did not trouble himself to weigh it to the fifth of a milligramme as the English version suggests. This habit of translating foreign units by some theoretical table is so common that it is really time to put in a plea for the exercise of common sense, which in this case would suggest $8\frac{3}{4}$oz. as a sufficient equivalent for 250 grammes, and in another would delete a residuum of 4 drams in a weight of nearly a ton.

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[1] "On the *Polar Star* in the Arctic Sea." By His Royal Highness Luigi Amedeo of Savoy, Duke of the Abruzzi, with the Statements of Commander U. Cagni upon the Sledge Expedition to 86° 34′ N., and of Dr. A. Cavalli Molinelli upon his Return to the Bay of Teplitz. Translated by William Le Queux. In two vols.; with 212 illustrations in the text, 16 full-page photogravure plates, 2 panoramas and 5 maps. Pp. 702 + xxii + xii. (London: Hutchinson and Co., 190)

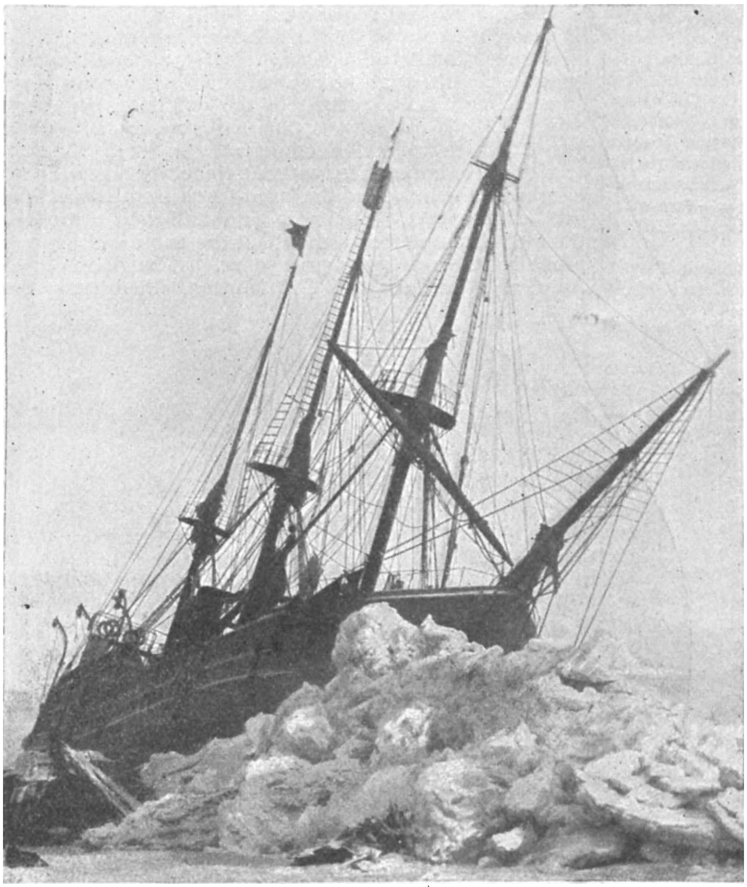

FIG. 2.—The *Polar Star* after the Ice Pressure. (From "On the *Polar Star* in the Arctic Sea."

The narrative of the Italian expedition has already been summarised in NATURE (vol. lxiv., 1901, p. 158), and it need not be repeated. The first of the volumes before us supplies many additional particulars as to the first navigation of Queen Victoria Sea, and the long struggle with the ice before the *Stella Polare* reached the northern limit of the Franz Josef Land archipelago beyond Rudolf Island. It deals with all the usual incidents of a winter sojourn in high latitudes, made in this case unexpectedly hard by the party being obliged to leave the ship, which had been specially prepared for wintering in, and to camp instead in extemporised tents. There are few references to scientific work, but observations were made and collections obtained which are being discussed in a series of volumes by Italian specialists. Enough is said, however, to show that the observations must have been frequently interrupted. The difficulties of high wind and snowdrift proved much greater than were expected with regard to the meteorological instruments, in the management of which some preliminary experience at a high-level observatory in Europe would have been of great assistance. The magnetic hut, too, suffered from stress of weather; but we hope that the results obtained will yet prove of value.

Most interest naturally attaches to the second volume, which deals mainly with Captain Cagni's fine attempt to reach the Pole. This attempt proved more nearly successful than any sledging expedition before or since, and it is narrated by the captain himself. There is no doubt that if the commander of the expedition had sufficiently recovered from the serious frost-bite from which he suffered he would have led the advanced party to the farthest point. The pluck and endurance of the Duke of the Abruzzi have been amply proved, while the fact that when himself disabled he insisted none the less on his second in command carrying out the programme speaks volumes for his generosity and patriotism. The expedition was a private one, planned to gratify the laudable ambition of an illustrious personage, and no one could have reasonably objected if the commander had changed his plans and stopped the expedition when he found he could go no farther. Captain Cagni and the three Italian alpine guides who accompanied him were worthy of the confidence reposed in them, and they were rewarded by being able to carry the Italian flag a little nearer to the Pole than the flag of any other nation has yet been taken. Beyond observations of latitude, no scientific work was possible on this arduous journey; but the result showed clearly that, given a sufficiency of dogs, no piece of polar travel need prove too difficult for resolute men. The dogs of the *Stella Polare* not only drew the sledges, but, as in Nansen's case, they furnished a food-supply for their surviving comrades, and in this case towards the end for the explorers themselves. It is curious to find that the exhaustion of provisions, or even of the petroleum used for fuel, excited comparatively little interest so long as a few dogs were left to furnish meat and grease to burn for cooking it; but the utmost anxiety was caused by the wearing out of the aluminium stove and cooking utensils. As regards clothing, the Italians found woollen material much more useful and satisfactory than furs. The point is discussed at some length by Dr. Cavalli, who observed that light porous cloth allowed the perspiration to pass to the outside before freezing, and there it could be scraped off and the clothes kept comparatively dry; whereas when skin clothing of any kind was used, snow and ice were formed on the inner surface, and when warmed in the sleeping-bag the clothes were saturated with moisture.

The Italian and Norwegian members of the expedition appear to have been on the best of terms throughout, and but for the loss of the first party returning from the great journey over the sea-ice, their year in the Arctic regions must be pronounced a most successful one. What is now wanted in the interest of science is no mere dash to the Pole, no more experiments as to modes of travelling, but a repetition of the drift of the *Fram* from a point north of Bering Strait, with abundant equipment for oceanographical, meteorological and magnetic research. It would cost but a trifle compared with the expense of an expedition with dogs and stores enough to ensure reaching a very high latitude from any land base, and the value of the results is certain, though five years might not be too much to allow for obtaining them. It is a great opportunity, ready for some wealthy person with a love of solitude and science.

THE RESTORATION OF THE LAND OF CHALDEA.

TWO lectures by Sir William Willcocks, late Director-General of the Irrigation Works in Egypt, delivered before the Khedival Geographical Society at Cairo, have been published in a pamphlet,[1] a copy of which has been received. Sir William Willcocks, as is well known, is an enthusiast in irrigation matters, and has had a very large share in bringing Egypt to its present state of prosperity by the reorganisation of the canal and reservoir system, and in designing the new works that have recently been carried out at Assuan. The pamphlet under notice relates to the ancient country of Chaldea, which bears a great resemblance in its physical features to Egypt, the river Tigris being capable of performing the same functions as the Nile.

In view of the proposed Bagdad Railway, which will traverse this delta, the subject is of considerable interest. The author's view is that the resuscitation of the ancient canal system would create along the line of railway a country as rich as Egypt, the rent of which would pay for both railway and irrigation works, and leave a surplus "which only those can realise who have been in intimate touch with Egyptian Agriculture."

Bagdad lies at a distance of about 500 miles from the sea, measured along its course. From the city to the Persian Gulf is a country now completely desolate, but which formerly was one of the most fertile and populous districts in the world. Opis, situated on the banks of the Tigris, and which was at one time the wealthiest mart of the East, bears to the delta of the Tigris very much the same relation that Cairo bears to the delta of the Nile; and here were situated the head of the great canals which irrigated the delta. The great Nahrwan canal had its intake in this locality, and extended for a length of about 250 miles, feeding an immense number of subsidiary canals. This canal, for the first ten miles of its course, was cut through hard conglomerate rock to a depth of 50 feet, and was 65 feet wide, increasing lower down to 394 feet. These dimensions considerably exceed those of the largest irrigation canal in Egypt. It was described as late as 970 A.D. as flowing amid continuous and extensive villages, date groves, and well-cultivated lands, the whole region over an area of 4600 square miles containing a population, judged from the ruins left, that no spot on the globe could excel. Owing to neglect of the works the main stream of the Tigris became diverted, the old bed of the river silted up, and the ruin of the irrigation system became complete, and now the ruins of Opis and many other mounds of adjacent buildings spread like islands over the deserted plain, which is quite bare of vegetation. The author of the pamphlet estimates that there are about one and a quarter million acres of first-class land of the value of 38,000,000*l.* that could be reclaimed and once more made prosperous by an outlay of 8,000,000*l.*, and which would produce a rental of 3,840,000*l.* Beyond this is an area of one and a half millions of acres of less fertile land, that could also be reclaimed and cultivated.

The second lecture is a description of what Egypt will be in fifty years' time, according to the author's ideas, when the country "will attain a height of splendour and magnificence." which will surpass the great works of the days of the Pharaohs, which have survived the revolutions and catastrophes of four thousand years.

THE DALTON CELEBRATIONS AT MANCHESTER.

THE Manchester celebrations in connection with the centenary of Dalton's atomic theory began on Tuesday afternoon, May 19, when Prof. F. W. Clarke, chairman of the International Commission on Atomic Weights, delivered the "Wilde" lecture on "The Atomic Theory" to the Manchester Literary and Philosophical Society. Addresses were presented on behalf of the Royal Society and the Chemical Society, and a message was received from the Russian Physico-Chemical Society. In an admirable discourse Prof. Clarke sketched the history of the atomic theory from its first conception in the minds of Greek philosophers down to the present day. He pointed out the directions in which the atomic theory would probably develop, but declared that the problem of matter would never be solved until the atomic weights of the elements had been finally settled. "Who," he asked, "will establish the Dalton Laboratory for pure research, and so give the work which he started a permanent home?"

In the evening the Literary and Philosophical Society gave a dinner, at which the principal guests were Profs. Clarke and van 't Hoff, Prof. A. E. Armstrong, Mr. Brereton Baker, Prof. P. F. Frankland, Mr. Vernon Harcourt, Dr. Harden, Sir James Hoy, Prof. Kipping, Dr. W. H. Perkin, sen., Sir William Ramsay, Prof. Emerson Reynolds, Sir Henry Roscoe, Prof. Smithells, Dr. Scott, Prof. Thorpe and Prof. Tilden.

In proposing the toast of the evening, the "Wilde" medallist—Prof. Clarke—and the Dalton medallist—Prof. Osborne Reynolds—Sir Henry Roscoe said that Dalton's atomic theory and Joule's discovery of the mechanical equivalent of heat reflected more distinction on Manchester than the city's association with the cotton industry or with the Ship Canal.

On Wednesday morning a special meeting of the Owens College Chemical Society was held to offer an address to the great Dutch chemist, J. H. van 't Hoff, now professor at the Berlin University. Prof. Dixon

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[1] "The Restoration of the Ancient Irrigation Works of the Tigris; or, the Re-creation of Chaldea"; and "Egypt Fifty Years Hence." By Sir William Willcocks. Pp. 71; with 10 plates. (Cairo: National Printing Department, 1903.)